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ATOMIC AND MOLECULAR PROCESSES

M. A. Biondi

Pittsburgh University

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PITTSBURGH ATOMIC SCIENCES INSTITUTE

TECHNICAL PROGRESS SUMMARY NO. 17

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Pittsburgh Atomic Sciences Institute

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Post-Doctoral Personnel:	J. G. Anderson J. W. Bozzelli E. Graham IV R. Johnsen H. H. Lo R. L. Myers T. L. Patterson Gladys Unger (as of Sept. 1974)
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Visiting Faculty:	None

TECHNICAL PROGRESS REPORT NO. 17

Pittsburgh Atomic Sciences Institute

Physics and Chemistry Departments

University of Pittsburgh

Pittsburgh, Pennsylvania

I. Summary of Research

The following research projects are identified by title, senior investigator(s) in charge of the work, and the general program to which they belong. This summary only covers advances during the period since our last progress report (dated April 30, 1974).

A. Laser Studies

1. Laser Ion-Molecule Reaction Rates (M. A. Biondi)

During the report period, initial tests were carried out with the drift tube-mass spectrometer apparatus which has been modified to permit optical studies of the excited states formed by particular ion-molecule reactions and to determine the spectral line profile (emission coefficient) as a function of wavelength for each optical transition. The initial tests were run on the charge transfer reaction

$$He^+ + N_2 \rightarrow He + N_2^{+*} \quad \begin{cases} \rightarrow He + N_2^{+*'} + h\nu \\ \rightarrow He + N^+ + N \end{cases} .$$

Although the NOAA flowing afterglow studies have shown that the optical yield from this charge transfer reaction is small (as a result of predissociation of the C $^2\Sigma_u$ state of N_2^{+*} into $N^+ + N$), we readily detected excited state production. It was possible to correlate an increased production of

excited states with electrically stopping the He^+ ions opposite the window in the drift tube guard rings, clearly demonstrating the excited state production by non-resonant charge transfer from He^+ ions.

2. Metal Atom Chemi-excitation (F. Kaufman, M. A. Biondi)

Much effort was expended on improving the performance of the piezo-electric scanning Fabry-Perot interferometer in our Na chemiluminescence studies. Because of the low light intensity in many of the experiments, coherent summing for 10 to 20 minutes is often necessary, and the short-time finesse in the 15 to 20 range could not be maintained due to slow drifts in the measured line shape. Improvements in the mechanical interferometer mount, in its temperature control, and in the stability and reproducibility of the ramp voltage generator output to the oscillating interferometer plate reduced these drifts to the order of 0.01 to 0.02 cm^{-1} over a period of 10 minutes compared with an instrumental width of about 0.04 cm^{-1}. Fluorescent Na emissions were obtained for calibration purposes by irradiating Na in flowing Ar carrier gas at temperatures of 490 to 520°K with a Na vapor lamp. These line shapes were compared with computed ones based on the convolution of Doppler line shapes (including hyperfine structure) with an instrumental function which included the Airy function, aperture function, and plate microdefect and non-parallelism (both spherical and wedge-type) functions. Unfortunately, a temperature difference of 100°K in such a theoretical Doppler line shape of the Na D-lines corresponds to a change of only 0.003 cm^{-1} in the full width of half height of about 0.110 cm^{-1}. The latter is so large mainly because of the broadening effect of hyperfine structure. Good agreement with theory for $T \sim 500$°K was obtained in early experiments, but recent measurements of fluorescent emissions have indicated considerably broader lines, a matter which is under active study.

Interesting new data were obtained in chemiluminescence experiments with Na excitation by discharged H_2. When high purity H_2 (Matheson U.H.P. grade) was used, Na emission was observed even when the microwave discharge on the H_2 or H_2-Ar stream was 50 to 60 cm upstream of the cell, i.e., under conditions where no emission had been observed in our earlier experiments, but in agreement with other published work. Approximate line widths were also somewhat narrower than we had found earlier, corresponding approximately to temperatures in the 1100°K range, but these may still be too high as suggested by the abnormally broad fluorescence line shapes. The H_2 discharge excitation experiments will now be concluded, and Na emission due to O, O_2, and O_3 reactions in discharged O_2 will be examined.

3. Production of Excited States by Electron-Ion Recombination (M. A. Biondi and E. C. Zipf

Our studies of the production of excited states by the dissociative recombination of vibrationally and electronically excited diatomic and polyatomic ions continue. Within the past few months we have added additional high resolution optical instrumentation that will permit a more detailed study of the new molecular band system produced by the dissociative recombination of vibrationally hot CO_2^+ ions that have never been observed before in emission but are very efficiently excited by this mechanism. The possibility that other polyatomic ions, when properly excited, could lead to the population of heretofore unidentified excited states that have laser utility is sharply emphasized by these preliminary results.

In order to pursue this study in a more informed way a new recombination system is presently under construction that will allow us through the use of a 1 megawatt tunable dye laser to directly measure the rotational and vibrational population distributions of the parent ions, to study vibrational

and rotational excitation and relaxation processes within the plasma itself (with particular attention to the consequences of charge transfer) and to study the vibrational distribution of excited fragment molecules produced by recombination. This system will permit specific recombination measurements under circumstances where the precise quantum mechanical identity of the parent ions is uniquely known and its concentration accurately determined by laser fluorescence techniques.

4. Processes Involving Metastable Species (E. C. Zipf)

A new series of metastable experiments have been initiated in the SPF vacuum chamber of the Lewis Research Center that are designed to measure the absolute chemiluminescent yields resulting from the deactivation of a large number of different metastable species. These experiments take advantage of the extraordinary pumping speed (~ 1 million liter/sec and the large dimensions of this vacuum chamber (120 ft. high, 100 ft. wide) to study the excitation and depopulation of conventional metastable states and of new species never studied before (either because of their enormous reactivity or because of their tendency to predissociate into excited atomic fragments). Not only do these studies measure the overall efficiency of these energy transfer processes at room temperature but also measure the effective reaction rate coefficient as a function of temperature over an unusually wide range from as low as 200°K to kinetic temperatures in excess of 200,000°K. This result is accomplished by measuring the velocity dependence of the reaction cross section directly. One of the special advantages of this approach is the possible discovery of resonance behavior at elevated kinetic temperatures that would be obscured in cruder microscopic experiments. Such resonant channels may well open new ways of manipulating an excited gas to improve the overall efficiency of an otherwise ordinary laser.

5. Time of Flight Experiments (E. C. Zipf)

We have continued our search for and study of new excited states with potential laser utility using Time-of-Flight [TOF] techniques. This study has benefited recently by our development of a new type of absolute surface detector with excellent sensitivity to low energy metastable states, permitting absolute cross section measurements previously impossible. Additional development work is currently underway to enhance the efficiency of this detector further and to extend its energy threshold to below 1.5 eV. The TOF experiments are also concentrating on a variety of Rydberg states as possible energy intermediaries as well as on the products of highly efficient predissociation reaction where the initial state is populated by a variety of convenient mechanisms such as (1) photon absorption, (2) electron impact, and (3) electronic energy exchange, and where the excited product states either emit photons directly or undergo efficient chemiluminescent deactivation.

6. Theoretical Studies - Laser Physics (J. N. Bardsley)

A. Charge Transfer into Excited States

Non-resonant charge transfer often results from the crossing of potential energy curves. Semi-empirical analyses have shown that systematic trends can be seen relating the cross section to the position of the crossing point, which can usually be computed easily. Our studies have shown that although it is possible to obtain good estimates of crossing points from measured cross sections, one cannot proceed in the opposite direction with any reliability, without making calculations of the strength of the charge-exchange interactions. Thus we have begun studies of these interactions. A paper on resonant charge-exchange interactions is being typed. The

results will make possible calculations of the charge transfer cross sections for all s-state ions, such as Hg^+.

B. Electron-ion Recombination

We are studying the distribution of excited atomic states formed during dissociative recombination. We have concluded that at the energies of a few electron volts typical of recombination induced by electron beams, many excited states can be formed including Rydberg states with high principal quantum numbers. On the other hand, in plasmas at moderate temperatures the number of possible final states is severely limited by the conservation of energy. Hence if highly excited states are required in a laser plasma the use of electron beams is desirable, whereas if one wishes to populate a single excited level selectively, the recombination induced by the ambient electrons may be more productive.

C. Drift Tube Reactions

In support of the drift tube reaction rate program we are performing calculations to determine the distribution of velocities among ions which are moving under the influence of an electric field. At moderate and large field strengths, we use the standard Monte-Carlo method to stimulate the motion of an individual ion through many thousand collisions, and equate the time average of this motion to the ensemble average of a swarm of ions. At low fields we follow a swarm of ions through a smaller number of collisions and compare the motion with and without the electric field. For the H^- - He system we have studied the dependence of the ion mobility on the interaction potential. By fitting the observed variation of the mobility with electric field strength we can derive an interaction potential and energy distribution which can be used to unfold measurements of reaction

rates. A paper on this topic will be presented at the Gaseous Electronics Conference in October 1974.

B. Atmospheric Radiation Backgrounds

7. Particulate Technology (W. L. Fite)

Activities have been divided into (1) laboratory experiments and (2) field instrument design.

The laboratory studies have first obtained certain parameters required for the field instruments. For example, a particle detector on a parachute will operate differently at different altitudes unltess the circuitry operates so as to keep the heated surface at a constant temperature. Measurements of filament cooling under air streams at different pressures and velocities have determined the range of filament powers that will be required in a parachute drop.

Major laboratory emphasis has been directed toward studying the water droplet effect. The particle detectors operate by a particle transferring its surface-ionizable impurities to a heated surface, followed by surface ionization of these impurities and the emission of a pulse of ions. It is found that water droplets also produce pulses of ions. It seems clear that it is the water itself, rather than the nucleus of a droplet, which might contain surface ionizable impurities, that causes the effect. It seems evident that the water interacts with the surface in such a way as to release surface ionizable impurities from the heated surface. The effect has been studied using droplets from a diffusion cloud chamber, which should be free of particulate nuclei, with several surfaces.

The interesting observation is that dry particulates produce ion pulses containing almost exclusively the ions Na^+ and K^+. The water droplet ion pulses are distinguished by having high levels of Rb^+ and Cs^+ in them as well. With tungsten surfaces, it is reasonable to believe that the water

oxidizes the tungsten, and the tungsten oxide is evaporated off, leaving a fresh bulk layer of tungsten below. The heavier alkali ions which could not migrate to the surface previously are not at the new surface and can be emitted. Clearly this type of explanation is not appealing for platinum surfaces however, where the same water droplet effect is observed (although at a greatly reduced level). We do not understand, as yet, the effect with platinum, which will probably be the preferred surface material for parachute experiments.

The possibility of using the water drop effect in order to distinguish between dry particulates and water droplets is obvious, i.e., through mass analyzing the emitted ions. However, our present efforts are to understand the effect with a view toward eliminating it, in the interest of having simpler, lighter equipment for the first flight tests.

Toward this end we are attempting to determine the number of ions emitted as a function of droplet size. While this can be done with dry particulates, by simply passing the particles through appropriate filters and observing the resultant pulse height distribution, water droplets clog such filters up. We are presently assembling an experiment in which highly charged water droplets will be produced by electrospraying. Then, in vacuum these ions will be sorted in an electric field for their e/m value. The particle will then have both its charge and velocity determined by an inductive detector, and finally will strike the surface. The relative importance of water droplets in a simple device will then be assessed.

With regard to design of flight instruments, we are reasonably well set in the circuitry design and are having prototype flight circuits built for us by Spacom Industries. Mechanical design is proceeding well, although final design will require more data on the water droplet effect.

It is our hope that we can construct a unit and fly it piggy-back on one of the balloon-parachute flights of our colleague, Dr. James G. Anderson, late next spring.

8. Radiative Properties of Simple Molecules and Atoms for Optical Discrimination Studies (E. C. Zipf)

Two separate experiments are underway concurrently to measure the absolute cross sections for the excitation of a variety of atomic, diatomic, and polyatomic states that relax radiatively by emitting photons in the wavelength range 300Å to 10μ. Conventional gases (e.g., CO_2, CO, NO, N_e, N, O, O_2, NO_2, NH_3, CH_4) as well as a variety of unexplored organic or chlorinated compounds are being actively studied. Major attention is being devoted to the extreme ultraviolet domain [EUV] in part because of atmospheric applications, but primarily because these absolute studies show that many molecules actually prefer to predissociate into excited atomic or molecular fragments rather than to radiate even though the radiative transition may be fully allowed. By measuring (1) the total inelastic cross sections for exciting these predissociating states, (2) the absolute photon emission cross section, and (3) by the identity and yield of final excited product states we are able to quantitatively assess the potential value of any of these intermediaries in laser applications or their role in the upper atmosphere in plumes or in nuclear events.

The systems currently in operation with some ARPA support include: (1) A high resolution inelastic electron scattering apparatus using two 8" hemispherical analyzers with 20 meV resolution and photon and metastable detectors. The experiment depends on multiple coincidence techniques to determine the initial excited state of the target, to observe the time

scale of the energy redistribution within the excited intermediary, and then to detect and identify the final product species.

(2) Conventional IR, visible, and vacuum ultraviolet excitation studies are carried out using a precision, high-resolution electron gun mated to a suitable monochromator (sometimes 2 simultaneously). A McPherson Model 225 spectrometer is used in the vacuum ultraviolet region for studies at wavelengths as short as 300Å, while McPherson 1/3-meter and Spex Czerny-Turner 3/4 meter instruments are used for longer wavelength studies. A high-resolution Fabry-Perot interferometer completes the complement of optical instrumentation supporting this experiment. This apparatus is now being reconfigured so that it can be used with a new 1 megawatt dye tuned laser acquired by our group with separate funds to vastly increase our sensitivity in the infrared using heterodyne techniques.

C. <u>Infrared Early Warning</u>

9. <u>Infrared Emission Resulting from Fuel-Oxidizer Reactions</u> (<u>F. Kaufman</u>)

Very good progress can be reported in two research areas:

(1) Experimental studies in our present flow tube apparatus which used a cooled PbS detector ($D^* \sim 1 \times 10^{11}$ cm $Hz^{1/2}$ $watt^{-1}$) and a circularly variable filter (CVF) of spectral range 1.1 to 4.3 µm, on the reactions $H + NO_2 \rightarrow HCl + Cl$, and $H + NOCl \rightarrow NO + HCl$ in which we attempt to measure the initial vibrational distribution of $OH^{\ddagger}$ or $HCl^{\ddagger}$ as well as their vibrational relaxation rate constants, at least for the fastest processes. For $OH^{\ddagger}$, experiments at total pressures of 0.77 to 2.8 torr, in He or Ar dilution, and at initial H and NO_2 concentrations of 0.3 to 1 mtorr produced emission in the fundamental band (1-0 and 2-1) near 2.7 µm as well as in the overtone band (2-0) near 1.5 µm. Preliminary analysis indicates about six times as much OH^v in v = 1 than in v = 2 and a total production of OH^v corresponding to less than about 10% of the total reaction products

(mainly $OH^{v=0}$) as determined by absolute intensity measurements using the published A-values of 3.3 and 2.6 sec^{-1} for the 1-0 and 2-0 transitions. Although the observed product distribution may be somewhat relaxed, it can not be substantially so, since the emission is measured only about 3 msec after the reactants are mixed and their concentrations are kept very low. In fact, excess NO_2 decreases the emission efficiently, consistent with a relaxation rate constant near 10^{-11} cm^3 sec^{-1} as would also be expected on the basis of the high-pressure limit of the OH + NO_2 recombination reaction. A more accurate estimate of the initial yield of OH^v is limited mainly by uncertainties of the mixing of the reactants and by the diffusional loss of OH^v by surface deactivation.

For the H + Cl_2 reaction, comparison can be made with published data by Polanyi's and Setser's groups who have studied this process at pressures of 10^{-4} to 10^{-2} torr in elaborate chemiluminescence experiments in large cells where relaxation processes can not be examined. At our high total pressures of 1 to 2 torr of He, but using reactant pressures of only 0.4 mtorr, we are seeing nearly unrelaxed initial product distributions as the following relative populations of HCl^v for v = 1 to 5 indicate. (Populations normalized to v = 3): Polanyi et al: 0.34, 0.74, 1.00, 0.21, 0.02; Setzer et al: 0.42, 1.3, 1.00, 0.20, 0.06; Bozzelli and Kaufman: 0.75, 1.15, 1.00, 0.26, 0.05. The latter data were obtained in a very simple flow tube apparatus in which various relaxation processes such as the fast reaction of HCl^v with excess H are easily studied.

Similar experiments for the faster, more energetic H + NOCl reaction have show HCl^v in v = 1 to 8, at a total pressure of about 1.5 torr He and reactant concentrations of about 0.25 mtorr. Relative concentrations of HCl^v were 0.73, 0.97, 1.00, 0.70, 0.41, 0.33, 0.17, and 0.09 for v = 1 to 8.

(2) A greatly improved apparatus has now been constructed which provides for an increase of one to two orders of magnitude in detectivity of infrared emission. Interchangeable detectors (In Sb, PbSe) are housed in an evacuated enclosure and receive radiation through a CVF which is cooled to 77°K so that background signal is reduced by several orders of magnitude. The detector-CVF system looks vertically into the flow cell through a low emissivity window and through another such window into liquid nitrogen. A preamplifier was constructed for one of the InSb detectors which uses liquid nitrogen cooled feedback and bias resistors and matched mosfets. The cooled load resistor can be matched to detector and background conditions. The radiation is chopped with a Bulova tuning fork chopper which eliminates a.c. noise and mechanical vibration. Initial tests of one of the InSb detectors (Texas Instruments) without cooled preamplifier but looking through a cooled CVF (3.2 to 6.4 μm, one of three interchangeable, cooled CVF's) have indicated a D* of 10^{12} cm $Hz^{1/2}$ $watt^{-1}$. For the more sensitive, background-limited InSb detector (Barnes Engineering) which is mounted inside the cooled enclosure with the above preamplifier, D* values well above 10^{13} are expected. After modification of the flow tube this greatly improved apparatus will now be brought to bear on measurements of infrared emission from various fuel-oxidizer reactions.

II. Publications and Technical Presentations

A. Publications

"Deactivation of He 2^3S by Thermal Electrons", R. K. Nesbet, R. S. Oberoi and J. N. Bardsley, Chem. Phys. Lett. 25, 587 (1974).

"Pseudopotentials in Atomic and Molecular Physics", J. N. Bardsley, Case Studies in Atomic Physics 4, 299 (1974).

"Complex Coordinate Studies of Resonant Electron-Atom Scattering", R. A. Bain, J. N. Bardsley, B. R. Junker and C. V. Sukumar, J. Phys. B 7, (in press, 1974).

"Calculations of the Positions and Residues of Regge Poles", C. V. Sukumar and J. N. Bardsley, J. Phys. B 8 (in press, 1975).

"Regge Poles and the Watson-Sommerfeld Transformation in Low Energy Atomic Collisions", C. V. Sukumar, S. L. Lin and J. N. Bardsley, J. Phys. B 8 (in press, 1975).

"Measurements of Positive Ion Conversion and Removal Reactions Relating to the Jovian Ionosphere", Rainer Johnsen and Manfred A. Biondi, Icarus, to be published.

"Measurements of Ion-Molecule Reactions of He^+, H^+, and HeH^+ with H_2 and D_2", Rainer Johnsen and Manfred A. Biondi, J. Chem. Phys. 61, 2112, 1974.

"Rate Coefficients for Oxidation of Ti^+ and Th^+ by O_2 and NO at Low Energies", Rainer Johnsen, F. R. Castell and Manfred A. Biondi, J. Chem. Phys., to be published.

"Variation of Electron-NO^+ Ion Recombination Coefficient with Electron Temperature", Chou-Mou Huang, Rainer Johnsen and Manfred A. Biondi, Phys. Rev., to be published.

"6300Å Intensity Variations Produced by the Arecibo Ionospheric Modification Experiment", Dwight P. Sipler, E. Enemark and Manfred A. Biondi, J. Geophys. Res. 79, 4276, 1974.

"Realistic Model of Hydrogen Constituents in the Lower Atmosphere and Escape Flux from the Upper Atmosphere", S. C. Liu and T. M. Donahue, J. Atmos. Sci., to be published.

"Associative Ionization of Ti, Zr, Gd, and Th in Collisions with O and O_2", H. H. Lo and W. L. Fite, accepted for publication in Chemical Physics Letters.

"Temperature Dependences of the Dissociative Ionization of CO_2", W. M. Jackson, R. T. Brackmann and W. L. Fite, Inter. Journal of Mass Spectr. and Ion Physics, 13, 237 (1974).

"Electrical Detection of Airborne Particulates Using Surface Ionization Techniques", R. L. Myers and W. L. Fite, (revised version) submitted to the Journal of Environmental Science and Technology, September, 1974.

"The Reaction of OH with CH_4", J. J. Margitan, J. G. Anderson, and F. Kaufman, Geophys. Res. Lett. 1, 80, 1974.

"Kinetics of the Reaction of OH with HCl", M. S. Zahniser, F. Kaufman, and J. G. Anderson, Chem. Phys. Lett. 27, 507, 1974.

"Vibrational Emission of NO_2 from the Reaction of NO with O_3", M. F. Golde and F. Kaufman, submitted to Chem. Phys. Lett.

"Hydrogen Chemistry: Perspective on Experiment and Theory", F. Kaufman, in Proceedings of Summer Advanced Study Institute on Physics and Chemistry of Atmospheres, to be published.

"Lifetime of the Metastable ^5S State of Atomic Oxygen", Phys. Rev. A 9, 568, 1974.

"Lifetime of the Metastable ^5S State of Atomic Oxygen", W. C. Wells and E. C. Zipf, Phys. Rev. A 9, 568, 1974.

"Dissociation of CH_4 by Electron Impact: Production of Metastable Hydrogen and Carbon Fragments", B. L. Carnahan, T. G. Finn and E. C. Zipf, J. Chem. Phys., 1974.

"Non-Thermal Rotational Distribution of $CO(A'\Pi)$ Fragments Produced by Dissociative Excitation of CO_2 by Electron Impact", M. J. Mumma, E. J. Stone, and E. C. Zipf, J. Geophys. Res., 1974.

"Electron-Impact Excitation of the ^3S and ^5S States of Atomic Oxygen", E. J. Stone and E. C. Zipf, J. Chem. Phys. 60, 4237, 1974.

B. Technical Presentations

"Electron and Ion Formation, Destruction, and Transport Processes in a Medium Consisting of Electrode Vapor", M. A. Biondi, invited paper, International Symposium on Electrical Breakdown in Vacuum, Swansea, Wales, July 15-19, 1974.

"Drift Tube Measurement of the Energy Dependence of the Reaction Rate for $NO^+ + H_2O + N_2$," H. L. Brown, Rainer Johnsen and Manfred A. Biondi, 27th Annual Gaseous Electronics Conference, Houston, Texas, Oct. 22-25, 1974.

"Ionization and Electron Heating by Metastable Atoms in Helium Afterglows", F. R. Castell and Manfred A. Biondi, 27th Annual GEC.

"Rate Coefficients for Oxidation of Ti^+ and Th^+ By O_2 and NO at Low Energies", Rainer Johnsen, F. R. Castell, and Manfred A. Biondi, 27th Annual GEC.

"Resonant Charge Transfer in Rb^+-Rb and Cs^+-Cs Collisions", B. R. Junker, S. Sinha and J. N. Bardsley, American Physical Society Meeting, Washington, D. C., April 23, 1974.

"The Watson-Sommerfeld Transform Applied to Heavy Particle Collisions", J. N. Bardsley and C. V. Sukumar, American Physical Society Meeting, Washington, D. C., April 23, 1974.

"Variational Calculations of Regge Poles for Electron Collisions", C. V. Sukumar, S. Lin and J. N. Bardsley, APS.

"Regge Poles in Atomic Physics", J. N. Bardsley, colloquium, JILA, Boulder, Colorado, September 27, 1974.

"OGO-6 Observations of 5577Å", an invited review paper presented by T. M. Donahue at the Summer Advanced Study Institute on Physics and Chemistry of Atmospheres at the University of Liege, Belgium, July 28-August 9, 1974.

T. M. Donahue presented an invited paper at the Solar Terrestrial Symposium, San Paulo, Brazil, June 15-20, 1974.

"Background Mass Spectra in Surface Ionization", R. L. Myers, M. A. Hender, W. L. Fite and T. M. Barlak, 22nd Annual Conference on Mass Spectrometry and Allied Topics, Philadelphia, Pa. May 19-24, 1974.

"Detection of Radicals and Excited Molecules in Dynamic Systems", W. L. Fite, invited paper presented at 22nd Annual Conference on Mass Spectrometry and Allied Topics, Philadelphia, Pa., May 19-24, 1974.

"Beam Methods in Charge Transfer Studies", W. L. Fite, invited paper presented at 22nd Ann. Conf. on Mass Spectrometry and Allied Topics, Philadelphia, Pa., May 19-24, 1974.

"Ionization Processes", W. L. Fite, invited paper presented at the Second European Study Group on Atomic and Molecular Processes in Ionized Gases, Innsbruck, Austria, September 2-5, 1974.

"Associative Ionization", W. L. Fite, lecture given at the Center for Nuclear Studies (C.E.N.), Saclay, France, September 12, 1974.

"Modulated Beam Mass and Phase Spectrometry", W. L. Fite, colloquium talk at University of Paris Sud, Orsay, France, September 11, 1974.

"Quadrupole Mass Spectrometers", W. L. Fite, invited paper presented at the British Mass Spectrometry Group Meeting, University of Warwick, Coventry, England, September 17-19, 1974.

F. Kaufman presented an invited review paper on Hydrogen Chemistry at the Summer Advanced Study Institute on Physics and Chemistry of Atmospheres at the University of Liege, Belgium, on August 1, 1974.

F. Kaufman presented a seminar on Stratospheric Ozone Photochemistry at the Meteorological Research Institute of Japan in Tokyo on August 21.

F. Kaufman presented a seminar on Laboratory Studies of OH Radical Reactions at the Chemical Society of Japan, University of Tokyo, on August 22, 1974.

F. Kaufman presented a paper on Gas Phase Hydrogen Atom Recombination at the 15th International Combustion Symposium in Tokyo, Japan, on August 27, 1974.

"Comment on the Production of $N(^2D)$ Atoms by Photoabsorption Processes and by Electron-Impact Excitation of N_2", E. C. Zipf, Trans. AGU 55, 1974. A paper presented at the spring meeting of the American Geophysical Union.

C. Other Activities Relating to ARPA

J. N. Bardsley visited the Joint Institute for Laboratory Astrophysics, May 29-30, 1974 to consult with D. Norcross, G. Dunn and A. V. Phelps.

M. A. Biondi and Rainer Johnsen attended the NATO Advanced Study Institute on Ion-Molecule Interactions, Biarritz, France, June 24-July 6, 1974 and contributed papers to various panels.

M. A. Biondi attended the E-Region Conference, Boulder, Colorado, August 13-15, 1974.

M. A. Biondi, W. L. Fite and F. Kaufman made presentations of their research programs to ARPA-STO in Washington, D. C., on July 24, 1974.

W. L. Fite served as a member of the Committee for Uses of the Space Shuttle for Molecular Beam Research.

F. Kaufman attended meetings of the Climatic Impact Committee of the National Academy of Sciences at M.I.T. on April 20 and 21, and on September 21 and 22, 1974. He also attended its summer study at Woods Hole, Mass., from July 7 to 20, 1974.

F. Kaufman is a member of a NASA-sponsored scientific study group on Combustion Experiments in Space and attended meetings of the group at the State University of New York in Stony Brook on March 30, June 3, and July 27, 1974.

F. Kaufman attended the 49th Chemistry Research Evaluation Meeting of the AFOSR Directorate of Chemical Sciences at Headquarters, Systems Command, USAF, Andrews Air Force Base, Md., on September 12, 1974.

E. C. Zipf launched a Nike Apache rocket (14.529 UA) carrying an Optical Mass Spectrometer as part of Project Alladin (June 1974). The instrument measured the composition of the neutral atmosphere from 75 to 133 km.

E. C. Zipf presented a lecture at the Naval Research Laboratory (May, 1974) on the auroral NO and EUV problems.

E. C. Zipf has attended a series of planning meetings for the resumption of our auroral studies in northern Canada (3 rockets to be launched during January) and for our participation in an expedition to study the equatorial anomaly from a site near Lima, Peru.

III. Visiting Scientists

F. Fiquet-Fayard, Universite Paris-Sud, Orsay, France, June 1974.

J. B. Delos, College of William & Mary, August 1974.

IV. Degrees Awarded

Gladys Unger (Ph.D., August 1974)

Senior Investigator	Est. Funds Expended and Committed (Thousands)
J. N. Bardsley	1.4
M. A. Biondi	9.2
T. M. Donahue	1.5
W. L. Fite	6.8
F. Kaufman	8.1
E. C. Zipf	3.5
Total Expended and Committed	30.5
Available Funds	179.5
Estimated Remaining Funds as of 10/1/74	149.0

University Accounting of Funds

Expended as of 9/30/74	25.0
Available Funds	179.5
Remaining Funds as of 10/1/74	154.5